

DISPOSAL OF THE RADIOACTIVE WASTES AT  
TRISAIA NUCLEAR RESEARCH CENTER

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16. Abstract  The method of classification, collection, and treatment of solid and liquid wastes produced at the Trisaia Nuclear Research Center is discussed. The problem caused by the possible migration of radionuclides due to the chronic or accidental loss either from the pits for solid wastes or from liquid containers in the sea is examined in detail.			
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DISPOSAL OF RADIOACTIVE WASTES AT  
TRISAIA NUCLEAR RESEARCH CENTER<sup>†</sup>

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1. CLASSIFICATION OF WASTES

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The volume of solid radioactive wastes produced at the Trisaia Nuclear Research Center (CRN) has been estimated at about  $1/2 \text{ m}^3$  per day. While the quantity of liquid waste has been calculated to be about  $600 \text{ m}^3/\text{day}$ , these have a specific activity of  $10^{-6} \text{ } \mu\text{Ci/cc}$  and a nuclide composition as shown in Table I.

The solid wastes are subdivided into several categories depending on the source:

- a) wastes from measurement and control laboratories;
- b) wastes from "hot" operations;
- c) residues from treated fuel elements.

The first type is defined as low specific activity waste. For this type of material we provide conventional packing composed, for example, of one or more sealed plastic containers; radiation does not exceed  $100 \text{ m rad/h}$  on contact from beta and gamma emitters and transferable external contamination does not exceed  $10^{-4} \text{ } \mu\text{Ci/cm}^2$  for beta and gamma emitters and  $10^{-5} \text{ } \mu\text{Ci/cm}^2$  for alpha emitters.

Contaminated radioactive wastes from alpha emitters are held

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\*Numbers in the right-hand margin indicate foreign pagination.

1) Health Protection Group, C.R.N., Trisaia-Policoro, Mt.

2) CNEN Health Protection and Inspection Division, Rome.

3) Health Engineering Laboratory, C.S.N., Casaccia, Rome.

<sup>†</sup>XV National Congress of the Italian Health Physics and Radiation Protection Association, Cagliari, September 29 - October 30, 1969.

to be of low activity when the mean specific activity does not exceed  $10^{-2}$   $\mu\text{Ci/cc}$ ; when this activity cannot be measured, they are defined as having low activity when the transferable surface contamination value taken at the external surface does not exceed  $10^{-4}$   $\mu\text{Ci/cm}^2$  [sic].

Liquid wastes are classified into high activity, medium activity, and low activity. Their classification is a function of specific activity.

-Definition of low specific activity: when the mean activity of the fission product mix in the discharge water is less than  $10^{-6}$   $\mu\text{Ci/cc}$ .

-Definition of medium activity: when the activity of the fission product mix is between  $10^{-3}$  and  $10^3$   $\mu\text{Ci/cc}$ .

-Definition of high specific activity: when the activity of the fission product mix is greater than  $10^3$   $\mu\text{Ci/cc}$ .

## 2. LOW ACTIVITY SOLID WASTES

The low activity solid wastes are collected in metal drums (see Fig. 1\*) and stored temporarily under a roof.

Once a sufficient number of drums has been collected they are carried to the burial area (Fig. 2\*), removed from the metal drums, and buried (Figs. 3\*, 4\*, 5\*, and 6\*).

For burying solids, a ditch is dug at the highest point of the Center's property (Fig. 2), 5 meters deep by 12 meters wide by 13 meters long. The soil strata concerned are sand and sand conglomerate.

When the ditch is completely full it is covered with earth then with an impermeable layer comprised of a plastic sheet or a sheet of tarred paper, then another layer of earth. With this system rainwater does not come into contact with the radioactive material but is drained away to the sides.

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\*Translator's note: figure not reproducible.

Fig. 1. Roof over wastes in temporary storage

Fig. 4. Emptying the drums

Fig. 2. C.R.N. Trisaia zone destined for burial

Fig. 5. Wastes laid on the bottom of the ditch

Fig. 3. Placing the drums in the ditch.

Fig. 6. Final placement of wastes in ditch

To evaluate the environmental and human contamination risks /39 associated with this type of liquid and solid waste elimination, a socio-ecological study was conducted in the area surrounding the C.R.N. facility.

In particular, are reported the results of the geological, mineralogical, and chemico-physical analyses evaluating the capacity of the soils involved to retain certain radio-nuclides under precisely defined experimental conditions, namely the "geological containment capacity" of the ditch, while more detailed studies are reported in other articles already published or in press.

Thus, a general geological study was first made, examining the stratigraphy of the soil in particular, both in detail around the burial zone and broadly throughout the Center's property and the vicinity. It was found that the soil is composed, going from bottom to top, of: grey-blue marly clays, ocherous sands, and sandy conglomerates from the early quaternary. Mineralogical analyses made on samples taken from the points concerned enabled us to establish that the basic clay is composed largely of inorganic material (about 90%) while 10% is inorganic.

The clayey mineral present is of the illitic type. The sand is mainly composed of quartz, albitic plagioclase, and calcite, with a little (about 9%) heavy minerals and an even smaller proportion (4-5%) of clayey minerals of the illitic and vermiculitic types.

A series of analyses was then conducted on representative samples of the various lithological types studied to obtain data indicating the greater or lesser aptitude of these rocks for absorbing certain radionuclides under well-defined conditions and as a function of certain parameters.

With these analyses, the distribution coefficient of the most important lithological types in the Trisaia subsoil (sands,

clays, and conglomerates) was calculated.

The distribution coefficients express the ratio between the concentration of radionuclides in the solid phase and their concentrations in the liquid phase; with these coefficients we can conveniently determine the aptitude of a natural material such as clay, clayey sand, etc. to absorb a certain cation more or less completely.

However, the value of this coefficient can vary according as the experiments are made, for each cation considered, with a certain pH, with distilled water or with variable cationic compositions, or with materials of different particle size, etc.

Thus it was our objective to determine, at least broadly, the distribution coefficients or  $K_d$  in synthetic water, thus having a saline composition defined in degrees of hardness either by varying the pH, by varying the extraneous ion concentration, by varying the particle size (for one and the same type of material), or by varying its mineralogical composition.

TABLE I

Radionuclide	Discharged activity/Yr	Fraction of total discharged act. (%)	Activity /day, $\mu\text{Ci}$
H 3	$4.5 \times 10^5 \text{ mCi}$	0.999	1.5
Sr 89	10 mCi	$2.7 \times 10^{-6}$	34
Sr 90	4 mCi	$8.9 \times 10^{-6}$	13
Y 91	10 mCi	$2.7 \times 10^{-5}$	36
Nb 95	4.8 mCi	$1.1 \times 10^{-5}$	16
Zr 95	10 mCi	$2.7 \times 10^{-5}$	37
Ru 103	2 mCi	$4.4 \times 10^{-6}$	7
Ru 106	1.8 mCi	$4.4 \times 10^{-6}$	6
I 131	$6 \times 10^{-3} \text{ mCi}$	$1.3 \times 10^{-8}$	0.02
Cs 137	4 mCi	$1.1 \times 10^{-5}$	16
Ce 141	4.2 mCi	$1.1 \times 10^{-5}$	16
Ce 144	15 mCi	$4.4 \times 10^{-5}$	50
Pm 147	6.6 mCi	$1.6 \times 10^{-5}$	22

Without going into technical details, we will report below the results of our investigations; these permit the following conclusions to be formulated:

1) In the sands there is a good, not to say optimal, cesium content even in the presence of weak concentrations of extraneous ions (such as  $K^+$ ,  $Na^{++}$ ,  $Mg^{++}$ , and  $Ca^{++}$ ) while this influence begins to be harmful with concentrations above  $10^{-1}$  N for  $Na^+$ ,  $Mg^{++}$ , and  $Ca^{++}$  and greater than  $10^{-2}$  N for  $K^+$ . Strontium on the other hand is retained in sands in smaller quantities than cesium under the same conditions, but not such as to permit complete passage and dispersion of this cation within a wide radius.

2) The particle size of the sand does not have much influence on this mechanism.

3) Cesium and strontium are absorbed to a greater extent in the lighter part of the mineral and in the part rich in clay.

4) The pH has no great influence on the selective absorption mechanism within a range of pH = 4 and pH = 8. Thus, the pH of the water-bearing layer remains constant around 7.5 and since this functions as a buffer solution we have, in nature, constant absorption conditions in the "optimum" range.

5) Experiments on the bottom-layer clay indicate that cesium is optimally absorbed, even in the presence of extraneous ions such as  $Ca^{++}$ ,  $Mg^{++}$ , and  $Na^+$  up to concentrations of  $10^{-1}$  N, while the absorption of  $K^+$  is diminished in concentrations of  $10^{-2}$  N.

6) Cesium is blocked from the sand and clay at a pH level of 3.

From the above results, it may be seen that the subsoil at the Trisaia CRN has physico-chemical, mineralogical, and chemical



properties such as to make the plastic wrapping, as the only container, sufficient for these radioactive wastes.

This is translated by a very small financial outlay per volume of material treated; however, with the passage of time and because of future volumes anticipated, also due to the small area available for burial, it will be necessary to make a reduction in volume. This can be achieved by burning the combustible materials and compacting the incombustible materials.

Although the safeguards are acceptable, the pre-selected zone is continuously under inspection: piezometers are placed around the ditch with the twin purpose of monitoring fluctuations in the piezometric surface of the water-bearing layer, and permitting water to be sampled to check any migration of radioactive materials. These instruments are made in galvanized iron tubing perforated with a series of holes. They are surrounded with gravel to facilitate water drainage. The gravel goes down to the clay level such that a water sample can be collected which has transversed all soil strata that might be involved in the possible migration of radioactive elements in the buried materials.

### 3. HIGH ACTIVITY SOLID WASTES

For disposal of high activity wastes a number of vertical bores were drilled and their walls finished with water-sealed cement (see Figs. 7\* and 8\*). These are located near the ditches for burying low activity wastes.

The radioactive materials comprising the high activity wastes are brought to the bores in a specially-made armored vehicle, and placed inside.

At the same time, or immediately thereafter, quick-drying cement is poured in such as to lump the material together into a single mass.

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\*Translator's note: figure not reproducible.

Figure 7. Ditches for solid high activity wastes

Figure 8. Bores to contain  
high activity solid wastes

Figure 9. Tanks for low  
specific activity liquid wastes

For the purposes of this operation, the filled well may be compared to a cement pillar set in the ground, containing radioactive materials inside.

#### 4. LOW ACTIVITY LIQUID WASTES

The low specific activity liquids are collected in tanks (see Fig. 9) and discharged through a conduit into the Ionian sea. Before the conduit was designed, a socio-ecological investigation was conducted. The results of the investigation (see tables 2 and 3) gave, from the safety point of view, the sensitivity of the inspection instruments used in it. For the conduit section between the collecting tanks and the sandpit, steel tubing will be used. The section between the handling room and the discharge into the sea will be made with two coaxial tubes. The tube will then receive active cathode protection for both the buried section and the section going into the sea. /42

The tubing of the section between the discharge tank and the box on the sandpit will be monitored by two separate systems: 1) periodically (i.e. at least once every six months) the tube will be closed by a flange and subjected to pressure; 2) continuously throughout its operation, the tubing will be monitored by two venturi tubes, one at the beginning and the other at the box on the sandpit, each with a different orientation. This, under optimum conditions, provides for 2‰ error in measurement.

It is extremely important for the reliability of the measurements that no air be present in the conduit; otherwise bubbles might form, falsifying the flowrate measurements in the venturi tubes: the conduit must always be completely full of liquid.

This excludes the possibility of exploiting the 40 meter height difference between the Center and sea level to discharge the collection tanks by gravity, unless a manual- or automatic-

TABLE 2

Nuclides	Maximum quantity for reaching maximum permissible contamination for population (Ci)
H3	$3.6 \times 10^4$
Sr 89	$1.2 \times 10^2$
Sr 90	$4.8 \times 10$
Y 91	$2.4 \times 10^2$
Nb 95	$1.1 \times 10^3$
Zr 95	$7.3 \times 10^2$
Ru 103	$9.6 \times 10^2$
Ru 106	$1.2 \times 10^2$
I 131	$1.2 \times 10$
Cs 137	$2.4 \times 10^2$
Ce 141	$1.1 \times 10^3$
Ce 144	$1.2 \times 10^2$
Pm 147	$2.4 \times 10^3$
Cs 134	$1.1 \times 10^2$
Co 60	$3.6 \times 10^2$

closing gate valve is placed downstream of the conduit. This option was discarded since it would have required continuous presence of a technician during discharge operations, or construction of an electric sub-station to supply the motors driving the valves. We thus placed a pressure valve in the box on the sandpit, calibrated to the same pressure as that of a 40 meter high column of water. This obviously requires a pump, for example, placed upstream of the conduit to obtain the necessary additional pressure for opening the valves for discharge.

In addition to the venturi tubes it is planned to install two /43 mechanical flowmeters, one upstream and one downstream of the operation; the difference in their readings, together with that of the venturi tubes, will show whether effluents are leaking out along the conduit.



TABLE 3

Nuclide	MPC popu- lation, $\mu\text{Ci/cc}$	MPI popu- lation, $\mu\text{Ci/day}$	L.F.	LOD water, $\mu\text{Ci/l}$	LOD milk, $\mu\text{Ci/l}$	LOD plants, $\mu\text{Ci/l}$	Concentration effluents, $\mu\text{Ci/l}$
H 3	$3 \times 10^{-3}$	6.6	1	$1.5 \times 10^2$	—	$3.3 \times 10^2$	2.5
Sr 89	$1 \times 10^{-6}$	$2.2 \times 10^{-2}$	$10^2$	$5 \times 10^{-1}$	$9 \times 10^{-2}$	$1.1 \times 10^{-2}$	$5.7 \times 10^{-5}$
Sr 90	$4 \times 10^{-7}$	$8.8 \times 10^{-4}$	$10^2$	$2 \times 10^{-2}$	$3.7 \times 10^{-3}$	$4.4 \times 10^{-4}$	$2.2 \times 10^{-5}$
Y 91	$2 \times 10^{-5}$	$4.4 \times 10^{-2}$	1	1	—	2.2	$6 \times 10^{-3}$
Nb 95	$1 \times 10^{-4}$	$2.2 \times 10^{-1}$	1	5	—	1.1	$2.2 \times 10^{-5}$
Zr 95	$6 \times 10^{-5}$	$1.3 \times 10^{-1}$	1	3	—	6.5	$6.3 \times 10^{-5}$
Ku 103	$8 \times 10^{-5}$	$1.7 \times 10^{-1}$	1	4	—	8.5	$1.1 \times 10^{-5}$
Ru 106	$1 \times 10^{-6}$	$2.2 \times 10^{-2}$	1	$5 \times 10^{-1}$	—	1.1	$1.0 \times 10^{-5}$
I 131	$1 \times 10^{-6}$	$2.2 \times 10^{-3}$	10	$5 \times 10^{-2}$	—	$1.1 \times 10^{-2}$	$3.3 \times 10^{-7}$
Cs 137	$2 \times 10^{-5}$	$4.4 \times 10^{-2}$	1	1	2.2	2.2	$2.2 \times 10^{-5}$
Ce 141	$9 \times 10^{-5}$	$2 \times 10^{-1}$	1	4.5	—	10	$2.3 \times 10^{-5}$
Ce 144	$1 \times 10^{-5}$	$2.2 \times 10^{-2}$	1	$5 \times 10^{-1}$	—	1.1	$8.3 \times 10^{-5}$
Pm 147	$2 \times 10^{-4}$	$4.4 \times 10^{-1}$	1	10	—	2.2	$3.7 \times 10^{-5}$
Cs 134	$9 \times 10^{-6}$	$2 \times 10^{-2}$	1	$4.5 \times 10^{-1}$	1	1	—
Co 60*)	$3 \times 10^{-5}$	$6.6 \times 10^{-2}$	10	3.3	—	$3.3 \times 10^{-1}$	—

\*) Not stated, but found in muds.

Since the uncertainty of the measurements, from the conservationist point of view, is considered as an effective loss in the conduit, uncertainties up to 10% of the daily flowrate are considered acceptable. This value, as demonstrated by ecological research, is broadly acceptable. When the uncertainty values are greater than 10%, the entire system will be inspected to ascertain whether there is actually a loss or a dysfunction of the meters due, for example, to the presence of air bubbles in the conduit.

If, after the inspection and maintenance, the values read off have less than 10% uncertainty they will be held to be valid; if not, the actual loss along the conduit will have to be investigated. For this purpose there is a wide safety margin, even covering com-

plete breakage, and, because of this, operations can take place on the conduit for a fairly long space of time. In fact, it has been estimated that, to produce saturation of the water-bearing layer, a volume of liquid equal to the capacity of one million tanks must be discharged into the layer. Thus if one tank were to be discharged per day, one million days would be available to repair any damages without shutting down the plant, before the layer below the river bed was saturated, while contamination of the Sinni river would never reach the operating levels drawn off.

As has already been stated, the section between the box and the discharge point into the sea is double-jacketed. /44

The space between the two tubes will be filled with liquid under pressure; the pressure in this space will be maintained at a level less than the relative pressure of the discharge liquid and greater than that of the outside environment. A differential manometer reading will reveal any breakages in the conduit.

Where the receptivity of the sea is concerned, a study has been commenced in collaboration with other specialist groups, and an initial result has already been published. However, theoretically, using Frake's model, an initial evaluation of the sea's receptivity has been made which shows that the quantities of curies that the sea can receive without ecological danger is far greater than the actual needs of the Center.

## 5. MEDIUM AND HIGH ACTIVITY LIQUID WASTES

For the time being, no form of removal has been planned for these wastes. They will simply be stored in special tanks in a reinforced concrete building (Waste Building).

### a) High Activity Wastes

The high-level liquid wastes will be placed in two stainless

steel tanks with a capacity of  $9.5 \text{ m}^3$ . These are cooled by coiled tubes in which demineralized water circulates. When the first tank is full the solution is sent to the second tank after installation of a new container with the same capacity to function as reserve storage.

b) Medium Activity Liquid Wastes

For these we are providing selective storage according to the pH. They are divided into:

- neutral liquid effluents;
- acid liquid effluents.

The neutral liquid effluents will pass into two carbon steel storage tanks with a capacity of  $68 \text{ m}^3$ . It is planned that these tanks will be filled one at a time so that the maximum reserve capacity is always available. Consequently, at the end of the first filling phase, a new tank of the same capacity will be installed.

The acid effluents, almost entirely nitric acid, will be collected in  $68 \text{ m}^3$  stainless steel tanks, which will eventually be filled after the proper period of decay.

It must be borne in mind that this storage system is only temporary. It is expected that in the near future the liquid wastes will be solidified by suitable processes.

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